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Analysis of Flexible Pavement on the Basis of Deflection Basins

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ANALYSIS OF FLEXIBLE PAVEMENT ON THE BASIS OF DEFLECTION BASINS

BY

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RESEARCH REPORT

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ABSTRACT

The pavement at research park called Research Parkway and Discovery Drive was found Deteriorated within two years of the construction. The need to evaluate the extent of damage and the estimate of remaining life of pavement initiated the research study.

The analysis presented in this report is based on the measurements of the surface deflections and the layered elastic theory.

The life expectancy of the pavement can be estimated by the amount of pavement deflection developed within the pavement system. The parameters used in the analysis are the applied load, material of the pavement components and environmental effects. Trial and error method is used to estimate the in-situ moduli of the base course and the subbase course to best fit in the deflection basin. The modulus of the asphaltic concrete layer is determined from the falling weight deflectometer.

The deflections were measured by the Benkelman Beam equipment and falling weight deflectometer for comparison. The analysis is done by using the CHEVRON computer program.

The results of the analysis suggest that the asphaltic concrete layer may be the weaker layer and the probable cause of the early pavement deterioration.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

The need for maintenance of the pavement is a necessity because the stresses producing the defects in structural components are constantly working in all pavements. Such stresses may be caused by change in temperature or moisture content, by traffic, or by small movements in the underlying or adjacent earth. Cracks, holes, depressions, and other types of distress are the visible evidence of pavement wear. They are simply the end results of the process of wear which begins when construction ends. So, the maintenance of existing pavement facility is as important as design and construction of pavement.

One of the most important functions of a pavement engineer is to evaluate the existing pavement in service. It is necessary to know the condition of the existing pavement to establish a maintenance program. The condition of the existing pavement could be determined by either qualitatively or quantitatively. Obviously the qualitative determination could vary considerably from engineer to engineer. Thus a quantitative way to evaluate the existing pavement is more accurate. One of the biggest variables that must be evaluated is establishing a criteria for pavement failure. Pavement distress as noted by visual inspection may or may not be indicative of an unsound pavement. It is necessary to distinguish between functional and structural failure of pavement.

There are various techniques for evaluating the existing pavement system. It is paramount to recognize that the type of pavement rehabilitation to adopt is dependent upon a knowledge of factors that caused the failure of the pavement.

The pavement at the research park called Research Parkway which begins at Alafaya Drive and runs thru the research park area was found to be deteriorated considerably within two years of the construction. The pavement was designed to last for at least twenty years before terminal serviceability level of 2.0 was reached. The need to evaluate the extent of damage and the estimate of the remaining life of the existing pavement initiated the research study, entitled "Analysis of Flexible Pavement on the Basis of Deflection Basin", using Chevron computer program and deflections measured by the Benkelman beam equipment and falling weight deflectometer. The ultimate goal of the research report study was to collect the necessary engineering data for the pavement to determine the early surface damage and estimate the remaining life of the pavement.

The data was collected for a total of twenty one stations. Out of this the analysis was done for stations 1, 6, 8, 10, 12, 17 and 21. This was due to the fact that the deflection profiles plotted from the Benkleman beam data and falling weight deflectometer data did not matched closely for the other stations. The reason for this could be due the fact that the pavement had lot of ripples and the Benkleman beam follower tip has a point contact whereas the circular plate of falling weight deflectometer has an area contact. The difference in the type of pavement contact could have a considerable difference in the pavement deflection measurements (see Figure 1).

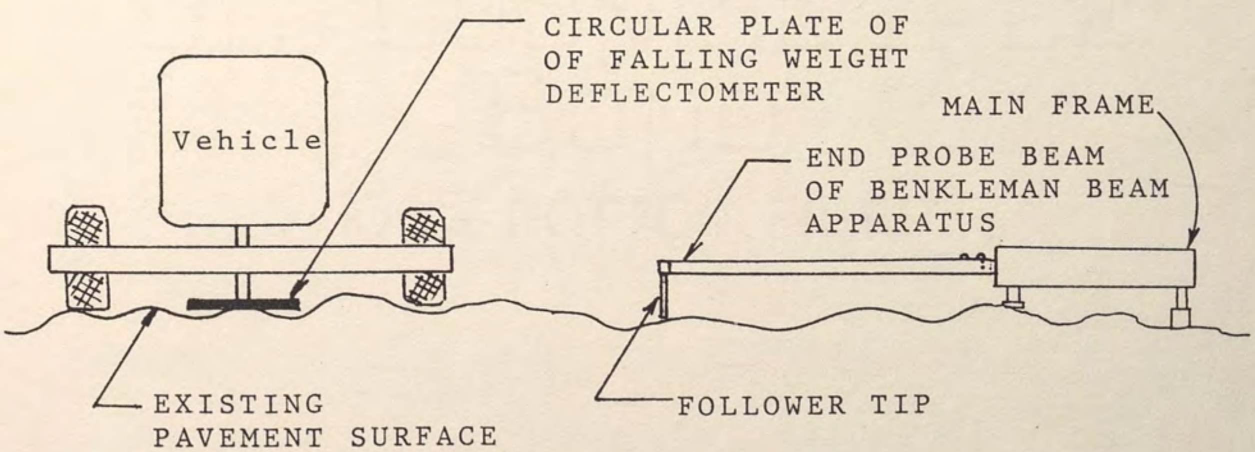

Figure 1. Contact Type Between Pavement Surface and Testing Apparatus

CHAPTER II

LITERATURE REVIEW

The field of pavement design and maintenance is a dynamic one, as the newer and better techniques keep emerging. There are a various techniques that are in use for design, evaluation and maintenance of existing pavement.

The method that is being used in this research report is based on layered elastic theory and limiting strains at the critical locations in the existing pavement system. Dormon and Metcalf (1) have very clearly explained that the tensile strain at the bottom of asphaltic concrete layer and compressive strain at the top of subgrade are the critical criteria for fatigue cracking of asphaltic concrete and subgrade rutting. The permissible tensile strain in asphaltic concrete layer and compressive strain in subgrade are dependent on two variables, the number of load repetitions and modulus of elasticity value for the different layers within the pavement system to be analyzed.

The number of repetitions to failure for the asphaltic concrete layer can be estimated by various graphs developed by Witczak, Monismith, Santucci, AASHO, etc. The fatigue curves developed by these investigators are presented in Principles of Pavement Design by Yoder and Witczak (2). The value of modulus is a required parameter for determination of number of load repetitions to failure.

The elastic modulus is typically calculated in either a laboratory testing or by use of the Van der Poel nomograph. The knowledge of mix properties such as bitumen content by volume and void content by volume, etc. will be used in this Van der Poel nomograph to determine the elastic modulus value of the asphaltic concrete layer of the pavement system.

The elastic modulus value of the asphaltic concrete layer of the existing pavement at the research park was calculated by the use of falling weight deflectometer. The computer that was connected to the falling weight deflectometer via sensors drew the graph of modulus verses depth at each test location as it measured the surface deflections. The graph was drawn at third and fourth drop of falling weight deflectometer at each test location. A typical printout modulus value is depicted in Appendix A.

In conjunction with the deflection measurements, environmental and loading conditions need to be taken into account, because some of the factors such as temperature of the pavement layers could influence the measured data considerably. The measured pavement deflections were adjusted by using the temperature adjustment factors to a standard temperature of 70 degrees Fahrenheit. The temperature adjustment factors were evaluated by the use of the graph (Figure 2) from Asphalt Overlay Techniques by The Asphalt Manual, Series no. 17 (3).

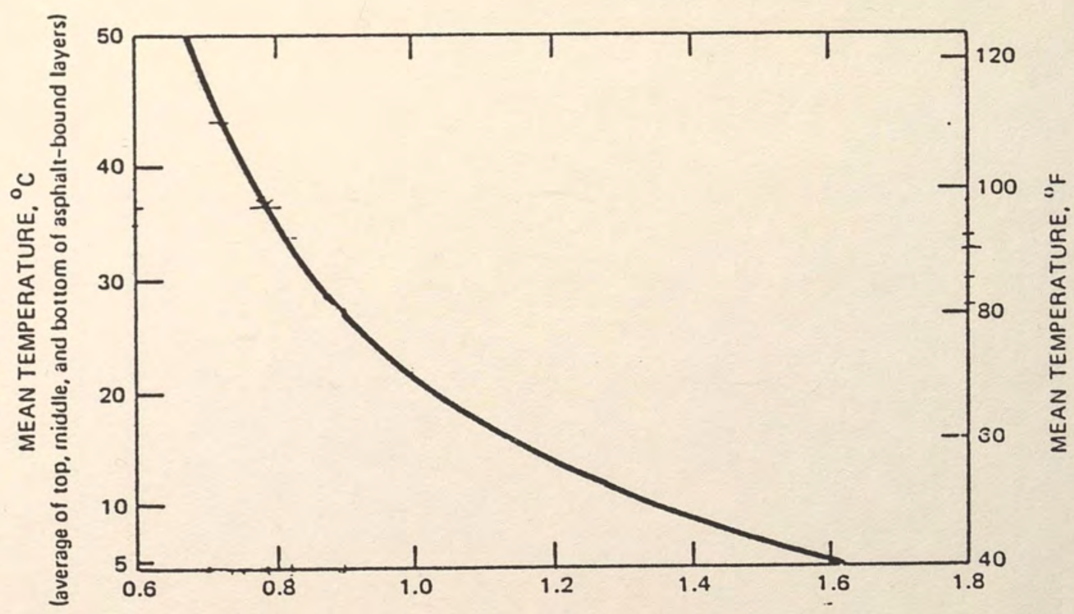

Figure 2. Temperature Adjustment Factors (3)

There can be many different types of cracks. The cracks can take place for a variety of different reasons such as overloaded vehicles. The major different types of cracks are alligator cracks, edge cracks, edge joint cracks, lane joint cracks, reflection cracks, shrinkage cracks and widening cracks. The causes for these different types of cracks and the proper repairing techniques are discussed in detail in "Asphalt In Pavement Maintenance by The Asphalt Institute Manual Series no. 16" (4) and "Manual for Condition Rating of Flexible Pavements" by Research and Development Division, Ministry of Transportation and Communication, Ontario, Canada (5).

Pavement distortion is any change of the pavement surface from its original shape. It is usually caused by such things as too little compaction of the pavement courses, too many fines in the pavement mixtures, too much asphalt, swelling of the underlying courses, or settlement. Like cracks, distortion can take place in many different forms. The major types of distortions are grooves or ruts, shoving, corrugations, depressions and upheaval. As again, the repair techniques are extensively described in "Asphalt In Pavement Maintenance by The Asphalt Institute Manual Series no. 16" (4) and "Manual for Condition Rating of Flexible Pavements" by Research and Development Division, Ministry of Transportation and Communication, Ontario, Canada (5).

Disintegration is the breaking up of a pavement into small, loose fragments. This includes dislodging of aggregate particles. If not stopped in early stages, it can progress until pavement requires complete rebuilding. Two of the more common types of early stage disintegrations are pot holes and ravelling. Repair techniques are also described in "Asphalt In Pavement Maintenance by The Asphalt Institute Manual Series no. 16" (4) and "Manual for Condition Rating of Flexible Pavements" by Research and Development Division, Ministry of Transportation and Communication, Ontario, Canada (5).

One of the useful concepts to estimate the pavement strength is spreadability of pavement. Spreadability concept is very clearly described by Dr. Shiou-San Kuo in a paper, "Analysis of Flexible Pavement on The Basis of Simple Deflection Basins Measured by Benkelman Equipment" (6). The spreadability is defined as the average deflection expressed as a percentage of maximum deflection and can be written mathematically as,

$$S_p = \frac{d_1+d_2+d_3+\ldots+d_n}{n*d_1} \tag{1}$$

where d_1 is the maximum deflection and d_2, d_3 ... d_n

are offset deflections from the center of loading. The lower spreadability value indicates that the pavement is weak. The normal range of spreadability for a satisfactory pavement is between 65 to 80 percent.

The pavement failure and remaining life concepts are discussed by M. W. Witczak and K. R. Bell in their paper called "Remaining Life Analysis of Flexible Pavements" (7). The pavement failure can be discussed by two different approaches, one being functional failure and the other being the structural failure. The newly constructed pavement at the beginning of the use has a serviceability level of, P_o . This serviceability level is decreased to a failure level, P_f , as the traffic is being carried by the pavement. The total number of load repetitions to reach this failure level, P_f, is, N_f.

In view of the pavement failure from structural standpoint (actual pavement damage), the distress in the pavement is not visible during initial period of time. The pavement damage will reach after certain load repetitions, N_{os}, have reached. This does not mean that the pavement is failed at this time, because it can still provide a relatively smooth and safe ride. Thus when the structural failure occurs, the serviceability level at that time, P_t, is much above the final serviceability level, P_f, reached after, N_{ff}, load repetitions.

The number of load repetitions required to reach serviceability, P_t, at the beginning of structural failure to, P_f, at, N_{ff}, load repetitions depends on various parameters such as pavement structure, volume of traffic, wheel load, environment, etc.

The concept of remaining life can be developed from the concept of pavement failure. When a new pavement is designed, it is designed to sustain a certain time , t, after the new pavement is put into operation. The number of load repetitions till that time can be denoted by, n_t. The damage to pavement at the time, t, can be expressed as,

$$D_t = \frac{n_t}{N_f} \quad (2)$$

Obviously for the failure condition $n_t = N_f$ and $D_t = 1$.

The remaining life at the time, t, then can be expressed as D_r, and

$$D_r = 1-D_t \quad (3)$$

or

$$D_r = 1 - \frac{n_t}{N_f} \quad (4)$$

or

$$D_r = \frac{N_f-n_t}{N_f} \quad (5)$$

J. Sharma and R. N. Stubstad used Falling Weight Deflectometer to determine the cause of pavement failure in their report "Evaluation of Pavement in Florida by Using the Falling Weight Deflectometer"(8).

Several sections of Interstate 75 in Florida were chosen for this research in order to determine modulus characteristics of the pavement layers. The elastic moduli for the typical section were determined by using a computer program developed at the Florida Department of Transportation: in situ stress-dependent elastic moduli, four layers (ISSEM4). The values of elastic moduli were used to better locate and control distress parameters in the pavement system.

CHAPTER III

THEORY AND OPERATION OF BENKELMAN BEAM AND FALLING WEIGHT DEFLECTOMETER

Benkleman Beam

The Benkelman beam is a device which is used to measure the rebound deflections of flexible pavement under the action of moving vehicular loads. The model that was used for the research analysis was the Soiltest Benkelman beam, model no. HT-350 which is designed to comply with the standard recommended practice for pavement deflection measurements, AASHTO T-256. A sketch of Benkleman beam is shown in Figure 3.

The principle of the Benkelman beam used to measure the rebound deflections is the simple lever arm principle. The Benkelman beam device used for the research had a lever ratio of two- to-one, however, the dial indicator was calibrated to read the true deflection of the beam probe point and absolutely no conversions were necessary. The main parts of the Benkelman beam equipment are, reference beam body, two part probe beam, rear zero adjust, dial indicator and battery operated vibrator.

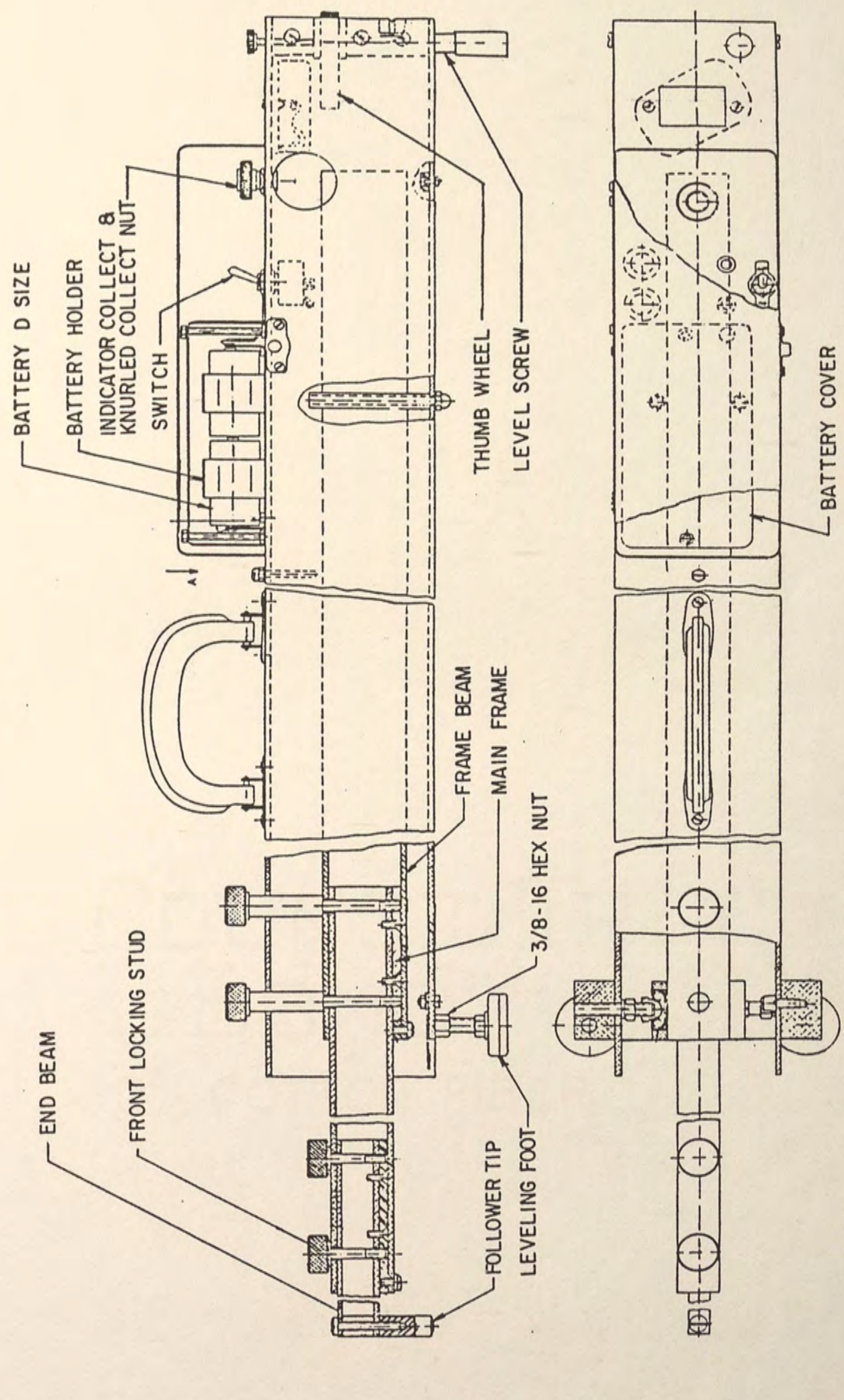

Figure 3. Benkleman Beam Equipment

The setting and operating procedure of the benkelman beam is fairly complicated and was followed very carefully to obtain the best results. First the box that covers the dial indicator was opened. Then the box for the batteries was opened and four "D" size batteries were installed inside this battery box. After this the probe beam was pulled out and locked in position with four beam locking studs which were stored in the reference beam body. Then the dial indicator was installed. The dial indicator installation is the most important operation in the setting of the Benkelman beam equipment. Since the dial indicators are the precision instruments, it should be handled with care. If any liquid lubricant comes in contact with the dial indicator it might collect dust and dirt. Extreme care was taken so that the dial indicator was protected from shock loads and bottoming of the tip.

Before the Benkelman beam was taken to the field, the dial indicator was installed as follows. The Benkelman beam was placed on a flat surface and lock nut and stop screws were loosened. The stop screw is the mechanical stop which protects the dial indicator from bottoming out when Benkelman beam is moved from one station to the next station with beams extended.

After the lock nut and stop screw were loosened, the center beam and the end beam were extended about two feet. After that the number of revolutions the dial indicator makes from one end to the other end were counted. The number of revolutions were counted to be twenty one. Then the collect nut was loosened, so that the dial indicator could be installed into the indicator collect. Then thru the hole on the side of the frame, a finger was placed on the inner frame beam and the inner frame beam was moved through its extreme up and down range. The stop screw was adjusted at this stage such that the dial indicator did not bottom out in the up position. This was made sure by noticing the lack of movement of dial indicator pointer when the stop screw was turned counterclockwise. At this point the stop screw was turned a little so that a few divisions of pointer movement was seen on the dial indicator. Then the lock nut was tightened against the frame.

After this the thumb wheel was turned until the bottom of the levelling screw was about one and half inches below the bottom of the frame. The beams were extended to their full length and locked into position with the locking studs. After this the lock nuts for the levelling feet were loosened and the front levelling feet were turned so that the dial indicator was about in its mid range. At this point the levelling feet were locked in with the lock nuts.

At this point the Benkelman beam was ready to be used with the dial indicator in its correct location and was protected from bottoming out.

Falling Weight Deflectometer

The surface deflections were also measured by using the falling weight deflectometer device. This was done so that a comparison could be made with the results obtained by use of the Benkelman beam equipment.

The falling weight deflectometer device uses an impulse load applied by a weight package and dampening system. A total of four seperate dynamic loads were applied at each test location. The impulse load delivered to the pavement had a duration of 20 to 30 milliseconds and it corresponds to the dynamic load applied by a moving vehicle. The range for the four seperate dynamic loads could be adjusted from 1500 lbs to 24000 lbs. The data collected was such that atleast one of four applied loads were lower and higher than 8710 lbs, which was the load under one dual tire of the truck used for benkleman beam equipment. The photographs of falling weight deflectometer are shown in Figure 9 on page 30.

The applied loads were adjusted by selecting the weight that drops onto a circular plate. A load cell and velocity transducer mounted at this location measured the impact load delivered to the pavement structure and the maximum deflection at the center of the load plate. The sensors mounted on a beam centered under the trailer tongue obtained six additional deflections. This was done to obtain a realistic shape of the deflection basin. This six additional sensors were spaced at 7.87, 11.8, 17.7, 25.6, 35.4 and 47.2 in. from the center of the circular load plate. The computer monitored system stored the load and deflection data for all four seperate load applications at each test location.

The theory behind falling weight deflectometer is basically same as the loaded axel, with the additional influence of dynamic loading as against to a static load. The vertical movement of the pavement is measured with the idea that the extreme movement indicates that a problem exists beneath the pavement at this point.

Some of the advantages of the falling weight deflectometer are that the falling weight deflectometer system measures the deflections rapidly and accurately on all types of pavements regardless of the pavement condition. It is a non-destructive testing and no damage is done to the pavement. The seven sensors used to measure the deflection basin are guaranteed absolute accuracy of 2% plus or minus of the actual deflections. The data is automatically generated by the computer monitored system. The graphical presentation of the layer moduli gave the value of the asphaltic concrete layer without the use of the laboratory method to calculate the elastic modulus.

CHAPTER IV

FIELD TESTING

In the early stage of the research study, a number of visits were made to the test site to identify of the extent of damage of the existing pavement. The approximate locations for collecting the field data were selected during these field visits. These locations were selected to reflect the condition of the pavement ranging from good to moderate to poor. Some of the locations selected were recently repaired by providing an overlay of asphaltic concrete layer. The main reason to collect the data for the pavement under various stages of damage was to cover the entire range of data for the analysis.

The study site was the Research Parkway at Central Florida research park. The Reaserch Parkway is the road that leads to the University of Central Florida main campus & runs thru the research park area (see Figure 4). As shown in this figure, the physical plant building is located off of Research Parkway just before it reaches campus. The inbound lanes of Research Parkway which was constructed from June to August 1982 had relatively more surface damage than

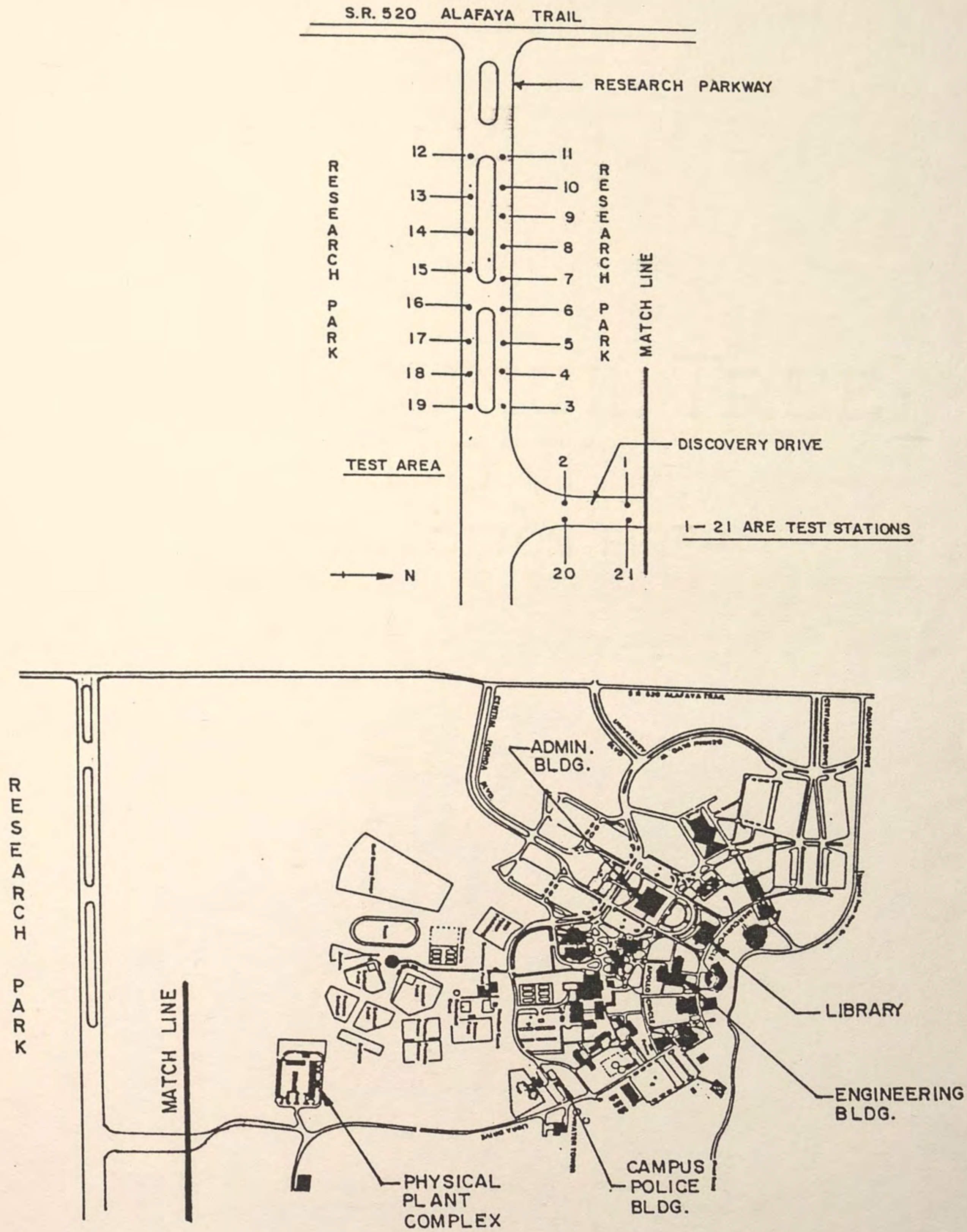

Figure 4. Test locations And Site Map

the outbound lanes. Much rippling and shoving of asphaltic concrete wearing surface was evident on the inbound lanes, eventhough cracking was visible on outbound lanes also. The Reaserch Parkway has a history of problems within months of its construction. The major cause of the inbound lanes problem is due to overstressing by heavy truck and construction equipment that hauled dirt to fill construction sites. The heavy truck and construction equipment caused the wearing surface to move and thus cause the rippling and shoving observed on the inbound lanes.

The section shown in Figure 5 is the typical cross section of the existing pavement for which the field test was conducted. This design cross section is basically F.D.O.T. type III asphaltic concrete pavement. The component layer, materials and dimensions are described as follows:

The wearing surface of asphaltic concrete is 1.5 inch (3.81 cm) thick, the thickness of the soil cement base is 8 inches (20.32 cm) and the compacted subbase layer of sand and gravel is 12 inch (30.48 cm) thick.

As mentioned earlier that the trouble of the pavement was first observed within few months of construction. The pavement of Reaserch Parkway and

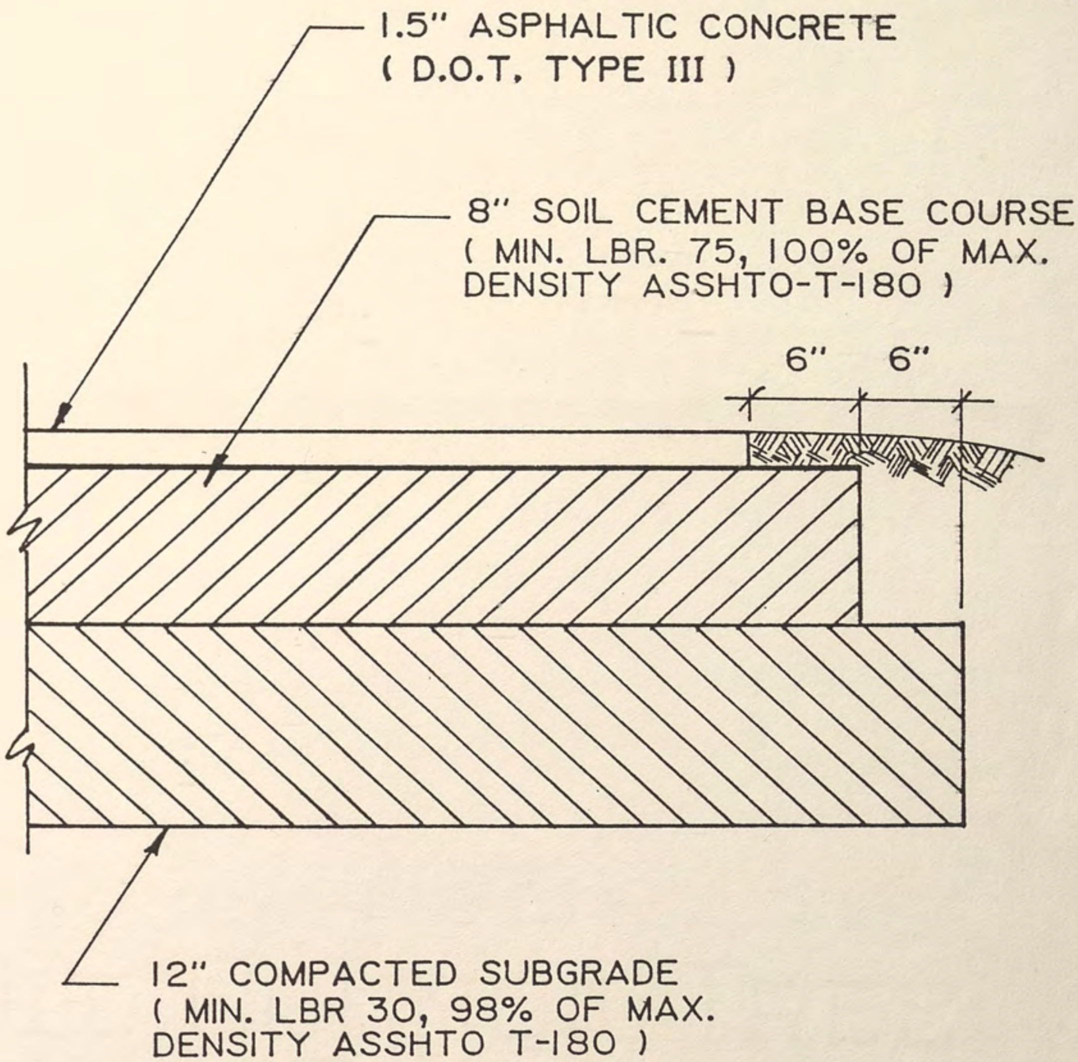

Figure 5. Typical Pavement Cross Section
on Research Parkway

Discovery Drive was constructed by Hubbard Construction Company from June to August, 1982. Geotechnical consultant firm, Jammal and Associates, Inc. of Winter Park were asked to investigate and evaluate the pavement deterioration as soon as the problems were noticed on the newly constructed pavement. According to their investigation, the major factor for the pavement deterioration was due to the high groundwater table. The results of soil borings and corings of the pavement sections indicated that water table was at or very near the top of the soil-cement base in several areas and the vidual inspections indicated that water table had risen to levels above the finished pavement grades in the past. This high groundwater may be true of a major factore of pavement distress other than the overstressing of the pavement.

The cracks that were found included reflection cracks, edge cracks, shrinkage cracks and widening cracks. The only types of distortions found were grooves or ruts. The disintegration types of defects included pot holes as well as ravelling. The majority of severe cracks and pot holes were found on the inbound lane of the Reaserch Parkway (see Figure 6).

Rebound deflections measurements were obtained by

Figure 6. Cracks and Pot Holes on Inbound Lane, Research Parkway

using Benkleman beam apparatus as well as Falling Weight Deflectometer. The deflection measurements by Benkleman beam is shown by photograph in Figure 7. In conjunction with the deflection measurements, environmental and loading conditions were also measured at the study site. These specific data included wheel weights, tire pressure, and surface temperature. The weight of the rear axel load was weighed 17420 lbs which is close to standard design equivalent vehicle having 18 kip rear axel load. The front tire pressure was 95 psi and the back tire pressure was 90 psi. The pavement temperature measured at alternate stations was 93 to 100 degrees fahrenheit (see Figure 8).

To measure the rebound deflections, the probe beam was slid between the dual tires of the rear axel of the loaded truck. The follower tip at the end of the two part probe beam rested on the pavement between the dual tires. As the truck moved ahead at creep speed, the total pavement rebound deflection was read by the means of the dial gauge. The pavement deflections were measured at 0, 12, 24, 36, 48, 60 and 120 inches from the starting point (see Figure 9). The starting point was set at nearly center of the dual tires. At every test station the spacings were marked on pavement

Figure 7. Deflection Measurements By Benkleman Beam

Figure 8. Pavement Temperature Measurement

Figure 9. Marking Spacings on Pavement for Measurement of Deflections

before the truck moved.

A total of 21 test spots were selected to collect the data. The data is tabulated in Table 1. The approximate distance between two consecutive stations was 200 feet, unless relatively good pavement was found at the next test spot. This was done due to the fact that the pavement was not damaged throughout the entire stretch. Table 1 clearly shows that the rebound deflections were small at station no. 12 and 17, which had the recent pavement overlay. This shows that the pavement is strong at these stations.

The rebound deflections were also measured by Falling Weight Deflectometer (see Figure 10). It was decided that the Falling Weight Deflectometer data will be obtained at the same location as that for the Benkelman beam. It was relatively easy to relocate the exact stations where Benkelman beam equipment was used for deflections measurements. The reason for collecting the data at the same stations was so that a comparison could be made. The deflection data by Falling Weight Deflectometer is listed in Table 2.

The Falling Weight Deflectometer equipment was provided by the Wood Engineering Consultants, Inc., in Orlando, Florida. The only Stations that were missed during the data collection were the stations no. 9 and

Table 1. Deflection Data By Benkleman Beam

Station No.	Temp. F	Dist. From Starting Point (in.)x10^{-3} 0	12	24	36	48	60	120
1	97	0	5	12	21	34	50	66
2	97	0	6	36	47	58	59	80
3	98	0	5	9	18	25	34	53
4	98	0	2	10	35	57	68	84
5	99	0	5	10	38	58	67	73
6	99	0	6	10	26	40	53	69
7	99	0	3	10	13	19	24	38
8	100	0	5	25	28	45	50	52
9	100	0	8	29	54	80	95	101
10	100	0	6	10	23	45	58	70
11	100	0	3	40	60	74	81	91
12	100	0	2	4	7	10	15	29
13	100	0	20	50	53	70	73	73
14	100	0	12	70	95	103	110	126
15	100	0	2	5	23	25	35	40
16	99	0	2	5	10	20	28	40
17	99	0	2	5	7	11	13	18
18	98	0	8	16	38	40	40	40
19	97	0	7	20	46	51	58	60
20	93	0	5	20	32	50	50	53
21	93	0	5	15	25	42	45	45

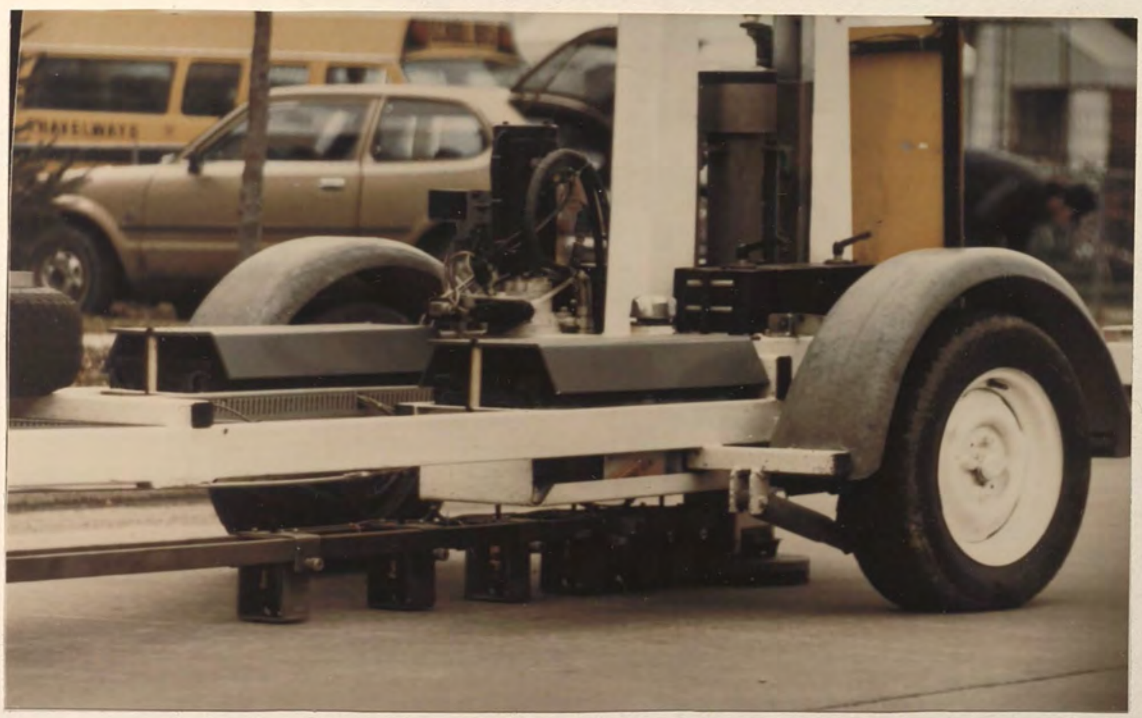

Figure 10. Falling Weight Deflectometer

16. The temperature was measured 81 degrees fahrenheit during the time the test was conducted. The deflections were measured at 0, 7.87, 11.8, 17.7, 25.6, 35.4, and 47.2 inches from the center of loading, where the center of loading was at 0.

Table 2. Measured Deflections By FWD

Station No. 1 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	4878	5069	7262	8740
0.0	6.77	6.73	11.85	15.39
7.87	6.38	6.30	11.10	14.29
11.8	4.61	4.49	8.15	10.59
17.7	3.39	3.46	6.02	7.83
25.6	2.48	2.40	4.45	5.83
35.4	1.73	1.73	3.07	4.09
47.2	1.10	1.22	1.89	2.52

Station No. 2 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5959	5959	9582	12394
0.0	20.16	19.80	34.84	46.14
7.87	10.55	10.43	18.66	24.57
11.8	6.57	6.46	12.17	16.22
17.7	4.21	4.13	7.72	10.47
25.6	2.52	2.52	4.88	6.61
35.4	1.69	1.69	3.03	4.13
47.2	1.38	1.38	2.01	2.60

Table 2. Measured Deflections By FWD (Cont.)

Station No. 3 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5625	5625	9200	12092
0.0	11.85	11.61	19.21	25.35
7.87	8.86	8.58	14.29	18.94
11.8	7.05	6.89	11.65	15.31
17.7	5.59	5.35	8.94	11.81
25.6	3.98	3.90	6.50	8.58
35.4	3.03	2.80	4.33	5.94
47.2	2.13	1.93	2.83	4.02

Station 4 No. : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5625	5641	9105	11918
0.0	18.19	18.07	29.96	38.07
7.87	11.38	11.50	20.63	27.01
11.8	9.06	9.13	14.84	19.88
17.7	5.83	5.91	10.75	14.09
25.6	4.29	4.29	7.24	9.80
35.4	2.17	2.28	4.96	6.42
47.2	1.06	1.18	3.31	4.09

Table 2. Measured Deflections By FWD (Cont.)

Station No. 5 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5832	5736	9359	12235
0.0	10.08	9.92	16.14	21.38
7.87	8.54	8.35	13.50	17.40
11.8	7.28	7.13	11.26	14.37
17.7	5.83	5.67	8.98	11.30
25.6	4.41	4.33	6.73	8.58
35.4	3.03	2.95	4.61	5.87
47.2	1.93	1.89	2.91	3.74

Station No. 6 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5339	5625	8390	10360
0.0	8.90	8.98	14.33	18.39
7.87	7.95	7.95	12.40	15.75
11.8	6.69	6.69	10.51	13.31
17.7	5.35	5.43	8.54	10.79
25.4	4.25	4.29	6.50	8.27
35.4	3.15	3.19	4.72	5.94
47.2	2.20	2.24	3.19	4.06

Table 2 : Measured Deflections By FWD (Cont.)

Station No. 7 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	6388	6436	9788	11934
0.0	13.86	13.66	22.05	28.50
7.87	9.72	9.65	14.61	19.13
11.8	7.40	7.36	11.97	15.28
17.7	5.39	5.28	9.17	11.61
25.6	4.13	4.06	6.81	8.62
35.4	2.28	2.20	4.80	5.79
47.2	1.26	1.18	3.35	3.90

Station No. 8 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5879	5848	9629	12394
0.0	10.12	9.88	15.59	19.53
7.87	8.66	8.46	13.31	16.57
11.8	6.26	6.22	9.76	12.24
17.7	4.13	4.09	6.65	8.43
25.6	3.07	3.11	4.80	6.14
35.4	2.09	2.13	3.43	4.49
47.2	1.38	1.42	2.56	3.31

Table 2. Measured Deflections By FWD (Cont.)

Station No. 10 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5879	5879	9518	12378
0.0	8.31	8.11	13.66	17.87
7.87	6.61	6.54	10.87	14.21
11.8	5.51	5.43	9.06	11.77
17.7	4.45	4.37	7.28	9.45
25.6	3.50	3.43	5.75	7.44
35.4	2.72	2.76	4.25	5.51
47.2	1.85	1.85	3.11	4.02

Station No. 11 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5752	5768	9264	12124
0.0	17.36	16.89	26.42	33.19
7.87	11.65	11.42	18.39	22.76
11.8	7.83	7.72	12.48	15.75
17.7	4.80	4.76	8.11	10.43
25.6	3.62	3.62	5.71	7.52
35.4	2.52	2.64	4.09	5.39
47.2	1.77	1.89	2.91	3.82

Table 2. Measured Deflections By FWD (Cont.)

Station No. 12 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	6054	5927	9534	12347
0.0	4.92	4.92	7.87	10.16
7.87	4.76	4.76	7.56	9.72
11.8	4.61	4.61	7.36	9.41
17.7	4.33	4.33	6.85	8.86
25.6	4.09	4.06	6.34	8.19
35.4	3.43	3.43	5.39	7.05
47.2	2.76	2.76	4.29	5.55

Station No. 13 : Deflection in inch x 10^{-3}

Dis. \ Load (Lbs)	5450	5482	9057	11902
0.0	23.90	23.07	38.78	53.07
7.87	14.72	14.29	22.72	28.35
11.8	10.00	9.76	15.71	19.80
17.7	6.34	6.26	10.24	12.99
25.6	4.29	4.29	6.65	8.62
35.4	2.72	2.80	4.29	5.55
47.2	1.89	1.93	2.76	3.74

Table 2. Measured Deflections By FWD (Cont.)

Station No. 14 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5832	5848	9328	12045
0.0	18.31	17.91	28.39	35.98
7.87	12.52	12.28	19.53	24.53
11.8	8.94	8.82	14.09	17.80
17.7	5.87	5.87	9.53	12.24
25.6	4.21	4.29	6.65	8.58
35.4	3.15	3.19	4.80	6.10
47.2	2.13	2.28	3.31	4.41

Station No. 15 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5720	5736	9423	12267
0.0	9.49	9.37	15.28	19.57
7.87	7.13	7.01	11.38	14.45
11.8	5.43	5.35	8.70	11.14
17.7	3.90	3.94	6.34	8.15
25.6	2.91	2.95	4.65	6.10
35.4	2.20	2.20	3.35	4.49
47.2	1.61	1.65	2.56	3.39

Table 2. Measured Deflections By FWD (Cont.)

Station No. 17 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5959	5975	9518	12378
0.0	3.66	3.70	5.98	7.87
7.87	3.50	3.50	5.59	7.32
11.8	3.35	3.35	5.31	6.93
17.7	2.99	2.99	4.88	6.42
25.6	2.72	2.68	4.33	5.67
35.4	2.28	2.28	3.62	4.72
47.2	1.81	1.81	2.83	3.74

Station No. 18 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5848	5784	9169	12061
0.0	15.63	15.00	24.88	32.80
7.87	10.20	9.88	16.18	20.39
11.8	7.17	6.97	11.54	14.45
17.7	4.92	4.76	7.91	9.92
25.6	3.58	3.58	5.75	7.20
35.4	2.64	2.76	4.21	5.28
47.2	2.01	2.24	3.11	3.98

Table 2. Measured Deflections By FWD (Cont.)

Station No. 19 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5530	5530	9200	12108
0.0	12.28	11.85	20.00	26.50
7.87	8.82	8.54	14.45	18.78
11.8	6.97	6.69	11.46	14.76
17.7	5.31	5.12	8.78	11.26
25.6	4.02	3.90	6.54	8.43
35.4	2.91	2.83	4.76	6.10
47.2	2.13	2.17	3.46	4.41

Station No. 20 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5927	5895	9661	12029
0.0	10.71	10.59	18.07	23.62
7.87	7.72	7.64	13.43	17.52
11.8	5.87	5.87	10.08	13.07
17.7	3.86	3.90	7.17	9.29
25.6	2.80	2.83	4.65	6.06
35.4	1.14	1.26	2.76	3.58
47.2	0.55	0.79	1.46	1.97

Table 2. Measured Deflections By FWD (Cont.)

Station No. 21 : Deflections in inch x 10^{-3}

Dis. \ Load (Lbs)	5736	5784	9455	12347
0.0	7.64	7.64	13.03	17.52
7.87	5.43	5.39	9.41	12.68
11.8	4.37	4.33	7.60	10.28
17.7	3.43	3.35	5.98	7.99
25.6	2.48	2.40	4.33	5.87
35.4	1.57	1.57	2.83	3.94
47.2	0.98	0.98	1.73	2.56

CHAPTER V

ANALYSIS OF RESULTS

Pavement analysis criteria, such as the tensile strain at the bottom of the asphaltic layer and vertical compressive strain at the top of the subgrade, are not easily measured in the field. The surface deflections have been used as indicators of pavement performance, and the difference in these pavement deflections due to the factors such as the amount of load, type of the material of the different layers and environmental effect have been used to determine the load carrying capacity as well as the remaining life estimate of the existing pavement.

ELASTIC LAYERED THEORY AND LIMITING STRAIN ANALYSIS

The method of analysis used in this report is based upon the elastic layered theory and limiting strains at the specific places as aforementioned within the pavement system. Dormon and Metcalf (1) justified that the tensile strain at the bottom of the asphaltic concrete layer and the vertical compressive strain at the top of subgrade are the critical standards related to the fatigue cracking of asphaltic concrete layer and subgrade rutting.

Asphaltic fatigue and subgrade rutting criteria are based on the allowable strains which are directly related to the number of load repetitions and modulus values of the different layers within the pavement system.

The Chevron N-layer computer program was used to do the elastic layered stress-strain analysis. The Chevron computer program that was used for the computations requires the values of Poisson's ratios of all the different layers. The values of Poisson's ratios were assumed for all the layers. The values selected were, for asphaltic concrete layer was 0.45, for base course and subbase course it was 0.35 and for subgrade it was assumed to be 0.30. In addition to the Poisson's ratios modulus values were assumed to run the Chevron program. The program output consisted of deflections at 0, 12, 24, 36, 48, 60 and 120 inches from the center of loading. It also calculated the values of tensile strain at the bottom of asphaltic concrete layer and compressive strain at the top of subgrade. The calculated deflections that best fit the field data determined the corerect tensile and compressive strain values. A typical output of Chevron N-layer is shown in Appendix B

For computing the modulus values of the asphaltic concrete layer there are several methods that are being used. The two of the most common methods are determination of modulus from the laboratory testing as well as from the Van der Poel nomograph. The method that was used for this research study was the use of the computer that was connected to the falling weight deflectometer.

RESULTS

The temperature adjustment factors were applied to the deflections measured by the Benkelman beam as well as the falling weight deflectometer. Before the temperature correction was applied to the falling weight deflectometer data, the data was converted for 8710 lbs weight by linear interpolation of measured values. The deflections calculated by the Chevron computer program were also plotted on the same graph for the respective stations. Out of a total of twenty one stations graphs were drawn for the seven stations (figures 11-17). The reason for selecting these seven stations was because the Benkleman beam and falling weight deflectometer data matched closely for these stations. These stations were station nos. 1, 6, 8, 10, 12, 17 and 21. Out of these seven, two of them, station no. 12 and 17 are for the good pavement. The pavement at these two locations was repaired recently by overlaying a new asphaltic concrete layer. The data is tabulated in tables 3-9.

The deflection profile is generally represented by spreadability which is a measure of pavement strength. It describes the slab action of the pavement. Mathematically spreadability is defined as

$$S_p = \frac{D_1 + D_2 + \ldots + D_n}{N \times D_1}$$

where D_1, D_2 etc. are the deflections at the center of loading and offset from the center of loading. The satisfactory pavements have spreadability values between 65 to 80 percent. The weaker pavements have lower spreadability values. The calculated spreadability values have been tabulated in table 10.

Table 3. Benkleman Beam and FWD Data
with Temperature Correction

Station No. 1
Temperature = 97 degrees F, 81 degrees F
Correction Factor = 0.79, 0.90

Dist. (in)	Benkelman Beam Deflec. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Falling Weight Deflectome. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Dist. (in)
0	13.2	10.43	15.32	13.79	0
12	12.2	9.64	14.23	12.80	7.87
24	10.8	8.53	10.54	9.49	11.8
36	9.0	7.11	7.79	7.01	17.7
48	6.4	5.06	5.80	5.22	25.6
60	3.2	2.53	4.07	3.66	35.4
120	0	0	2.51	2.26	47.2

Computer Output
Using Chevron Program

Modulus Asphalt	300000 psi
Modulus Base Course	500000 psi
Modulus Subbase	15000 psi
Modulus Subgrade	10000 psi

Distance (in)	Deflection (10^{-3} in)	Distance (in)	Deflection (10^{-3} in)
0	12.86	48	3.43
12	10.06	60	2.30
24	7.26	120	0.00
36	5.04		

Table 4. Benkleman Beam and FWD Data with Temperature Correction

Station No. 6
Temperature = 99 degrees F, 81 degrees F
Correction Factor = 0.78, 0.90

Dist. (in)	Benkelman Beam Deflec. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Falling Weight Deflectome. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Dist. (in)
0	13.8	10.76	14.99	13.49	0
12	12.6	9.83	12.94	11.65	7.87
24	11.8	9.20	10.96	9.87	11.8
36	8.6	6.71	8.90	8.01	17.7
48	5.8	4.52	6.79	6.11	25.6
60	3.2	2.50	4.92	4.43	35.4
120	0	0	3.33	3.00	47.2

Computer Output
Using Chevron Program

Modulus Asphalt	300000	psi
Modulus Base Course	500000	psi
Modulus Subbase	15000	psi
Modulus Subgrade	10000	psi

Distance (in)	Deflection (10^{-3} in)	Distance (in)	Deflection (10^{-3} in)
0	12.86	48	3.43
12	10.06	60	2.30
24	7.26	120	0.00
36	5.04		

Table 5. Benkleman Beam and FWD Data
with Temperature Correction

Station No. 8
Temperature =100 degrees F, 81 degrees F
Correction Factor = 0.78, 0.90

Dist. (in)	Benkelman Beam Deflec. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Falling Weight Deflectome. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Dist. (in)
0	10.4	8.11	14.20	12.78	0
12	9.4	7.33	12.13	10.92	7.87
24	5.4	4.21	8.90	8.01	11.8
36	4.8	3.74	6.03	5.42	17.7
48	1.4	1.09	4.39	3.95	25.6
60	0.4	0.31	3.12	2.81	35.4
120	0	0	2.28	2.05	47.2

Computer Output
Using Chevron Program

Modulus Asphalt	350000 psi
Modulus Base Course	500000 psi
Modulus Subbase	20000 psi
Modulus Subgrade	15000 psi

Distance (in)	Deflection (10^{-3} in)	Distance (in)	Deflection (10^{-3} in)
0	10.08	48	2.28
12	7.48	60	1.50
24	5.16	120	0.00
36	3.45		

Table 6. Benkleman Beam and FWD Data with Temperature Correction

Station No. 10
Temperature =100 degrees F, 81 degrees F
Correction Factor = 0.78, 0.90

Dist. (in)	Benkelman Beam Deflec. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Falling Weight Deflectome. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Dist. (in)
0	14.0	10.92	12.43	11.18	0
12	12.8	9.98	9.90	8.92	7.87
24	12.0	9.36	8.25	7.43	11.8
36	9.4	7.33	6.63	5.97	17.7
48	5.0	3.90	5.23	4.71	25.6
60	4.4	3.43	3.92	3.53	35.4
120	0	0	2.83	2.55	47.2

Computer Output
Using Chevron Program

Modulus Asphalt	360000 psi
Modulus Base Course	500000 psi
Modulus Subbase	17000 psi
Modulus Subgrade	12500 psi

Distance (in)	Deflection (10^{-3} in)	Distance (in)	Deflection (10^{-3} in)
0	11.20	48	2.76
12	8.55	60	1.83
24	6.04	120	0.00
36	4.11		

Table 7. Benkleman Beam and FWD Data with Temperature Correction

Station No. 12
Temperature =100 degrees F, 81 degrees F
Correction Factor = 0.78, 0.90

Dist. (in)	Benkelman Beam Deflec. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Falling Weight Deflectome. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Dist. (in)
0	5.8	4.52	7.20	6.48	0
12	5.4	4.21	6.92	6.23	7.87
24	5.0	3.90	6.73	6.06	11.8
36	4.4	3.43	6.27	5.65	17.7
48	3.8	2.96	5.82	5.24	25.6
60	2.8	2.18	4.94	4.45	35.4
120	0	0	3.94	3.55	47.2

Computer Output
Using Chevron Program

Modulus Asphalt	900000 psi
Modulus Base Course	990000 psi
Modulus Subbase	22000 psi
Modulus Subgrade	17000 psi

Distance (in)	Deflection (10^{-3} in)	Distance (in)	Deflection (10^{-3} in)
0	6.99	48	2.06
12	5.64	60	1.40
24	4.18	120	0.00
36	2.97		

Table 8. Benkleman Beam and FWD Data with Temperature Correction

Station No. 17
Temperature = 99 degrees F, 81 degrees F
Correction Factor = 0.78, 0.90

Dist. (in)	Benkelman Beam Deflec. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Falling Weight Deflectome. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Dist. (in)
0	3.6	2.81	5.46	4.91	0
12	3.2	2.50	5.11	4.60	7.87
24	2.6	2.03	4.86	4.38	11.8
36	2.2	1.72	4.45	4.00	17.7
48	1.4	1.09	3.95	3.56	25.6
60	1.0	0.78	3.31	2.98	35.4
120	0	0	2.60	2.33	47.2

Computer Output
Using Chevron Program

Modulus Asphalt 900000 psi
Modulus Base Course 990000 psi
Modulus Subbase 32000 psi
Modulus Subgrade 27000 psi

Distance (in)	Deflection (10^{-3} in)	Distance (in)	Deflection (10^{-3} in)
0	5.37	48	1.29
12	4.08	60	0.85
24	2.87	120	0.00
36	1.94		

Table 9. Benkleman Beam and FWD Data with Temperature COrrection

Station No. 21
Temperature = 93 degrees F, 81 degrees F
Correction Factor = 0.82, 0.90

Dist. (in)	Benkelman Beam Deflec. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Falling Weight Deflectome. (10^{-3} in)	Corrected Deflec. (10^{-3} in)	Dist. (in)
0	9.0	7.38	11.94	10.74	0
12	8.0	6.56	8.59	7.73	7.87
24	6.0	4.92	6.94	6.24	11.8
36	4.0	3.28	5.45	4.90	17.7
48	2.2	1.77	3.94	3.54	25.6
60	1.0	0.82	2.57	2.32	35.4
120	0	0	1.58	1.42	47.2

Computer Output
Using Chevron Program

Modulus Asphalt	350000 psi
Modulus Base Course	500000 psi
Modulus Subbase	22000 psi
Modulus Subgrade	17000 psi

Distance (in)	Deflection (10^{-3} in)	Distance (in)	Deflection (10^{-3} in)
0	9.40	48	2.01
12	6.84	60	1.31
24	4.64	120	0.00
36	3.06		

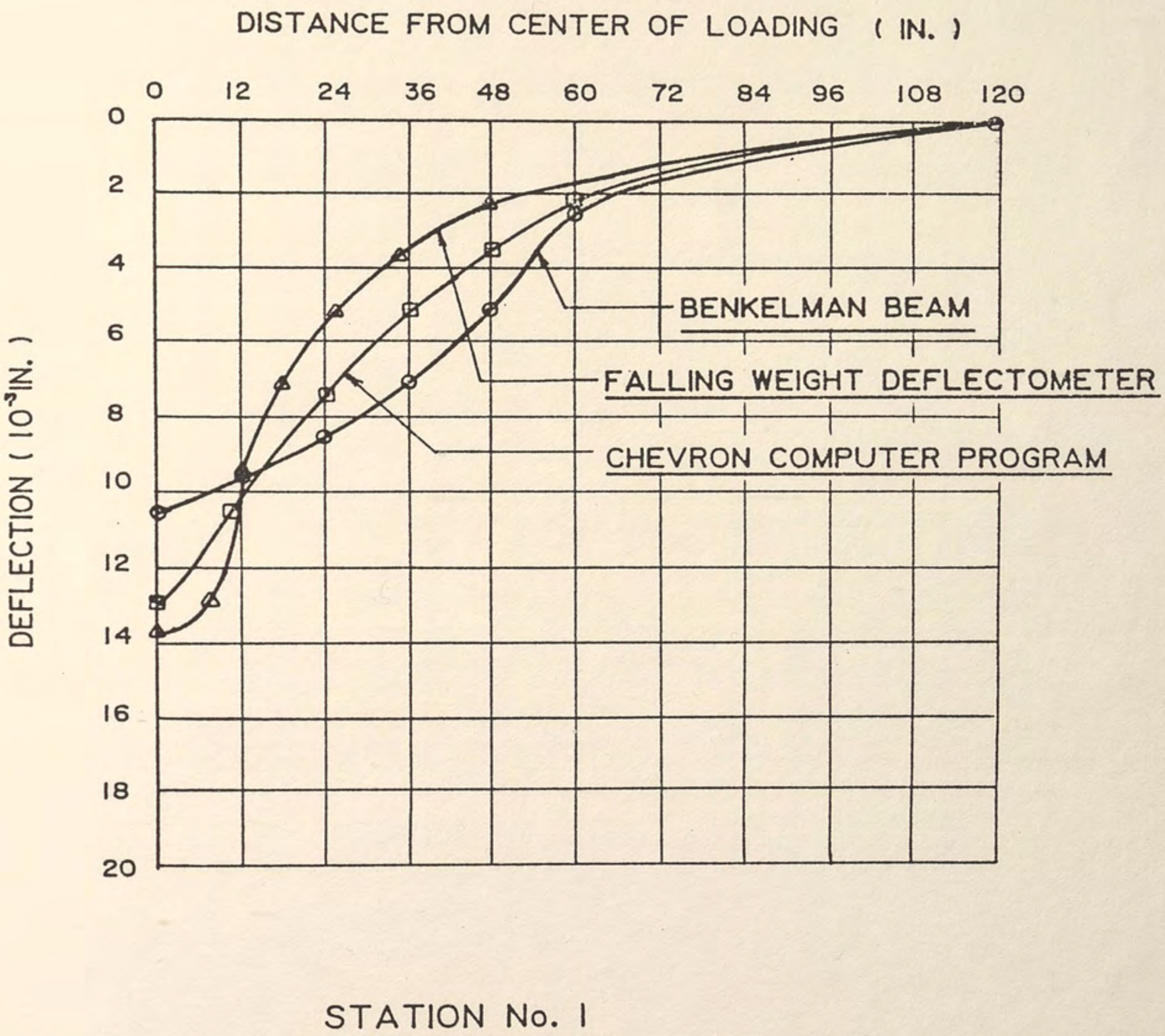

Figure 11. Deflection Basin from Station No. 1

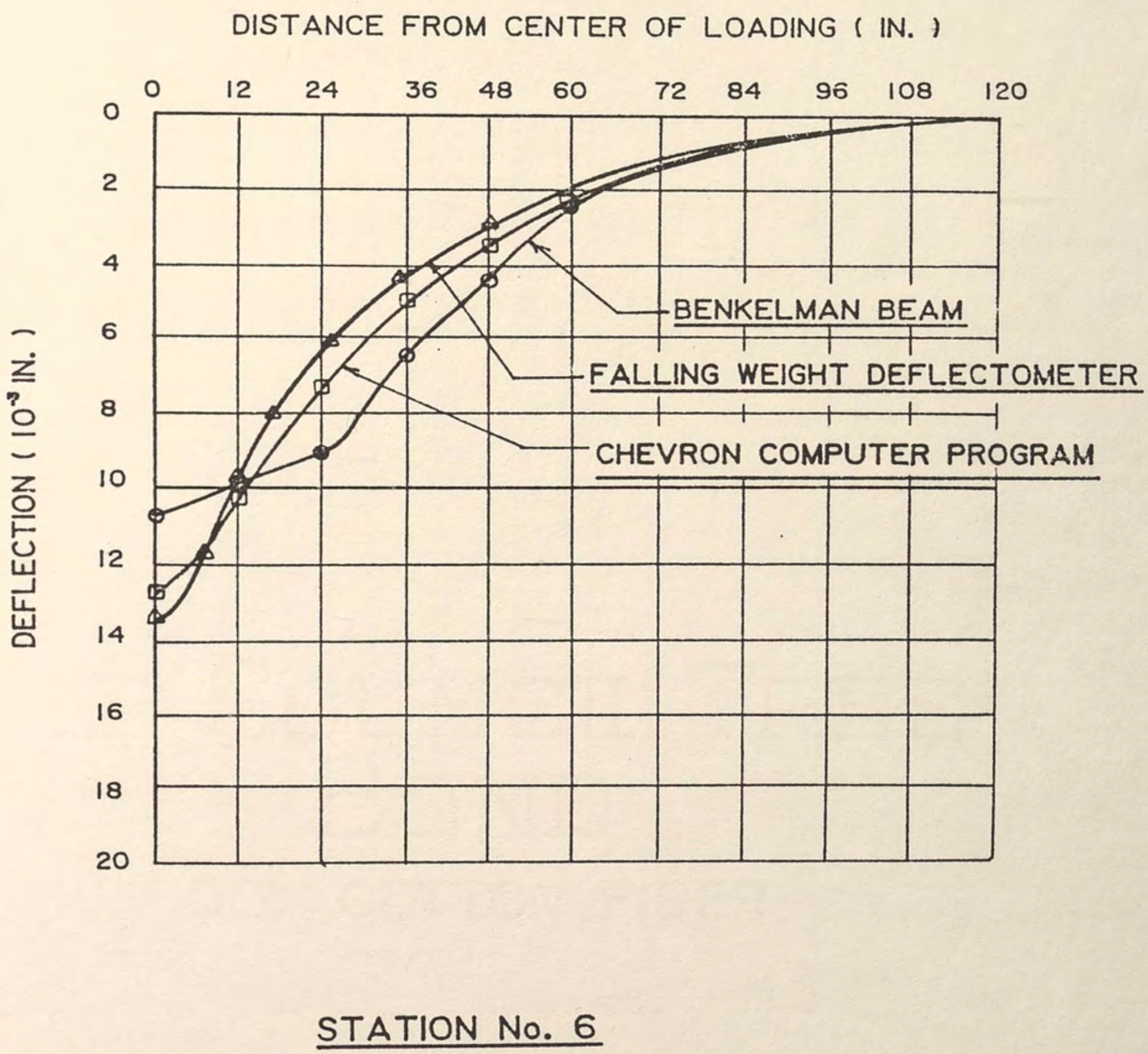

Figure 12. Deflection Basin from Station No. 6

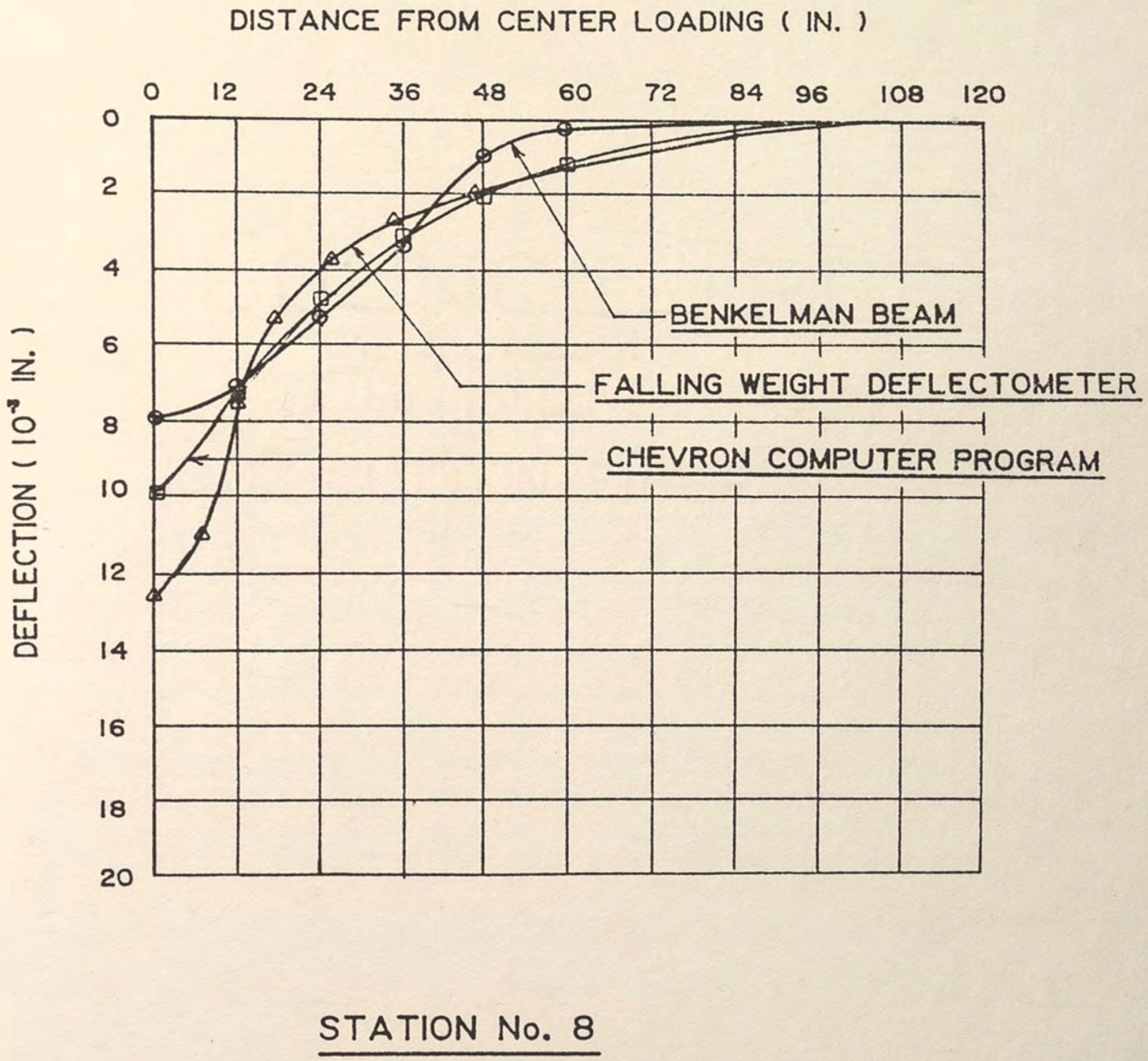

Figure 13. Deflection Basin from Station No. 8

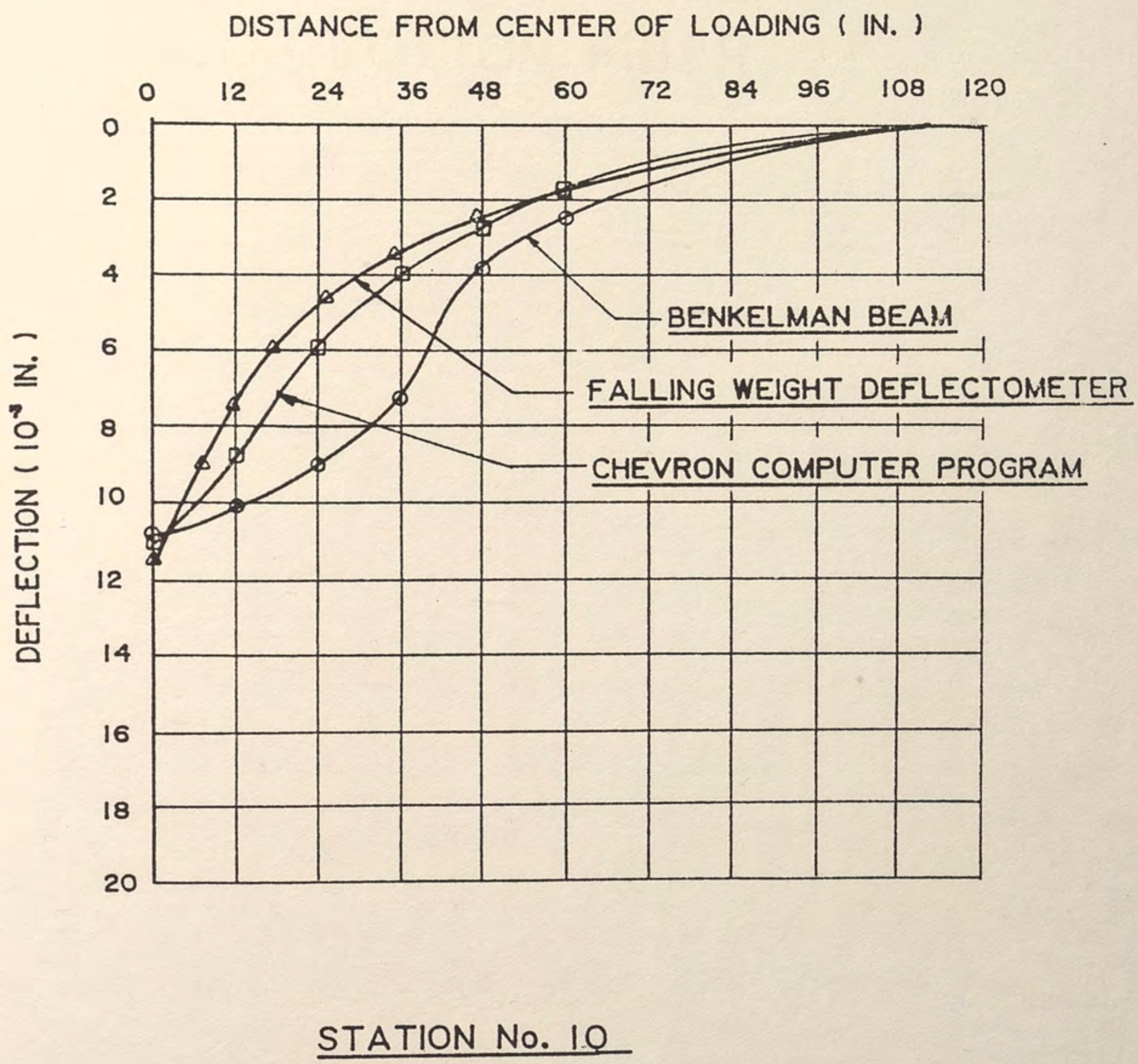

Figure 14. Deflection Basin from Station No. 10

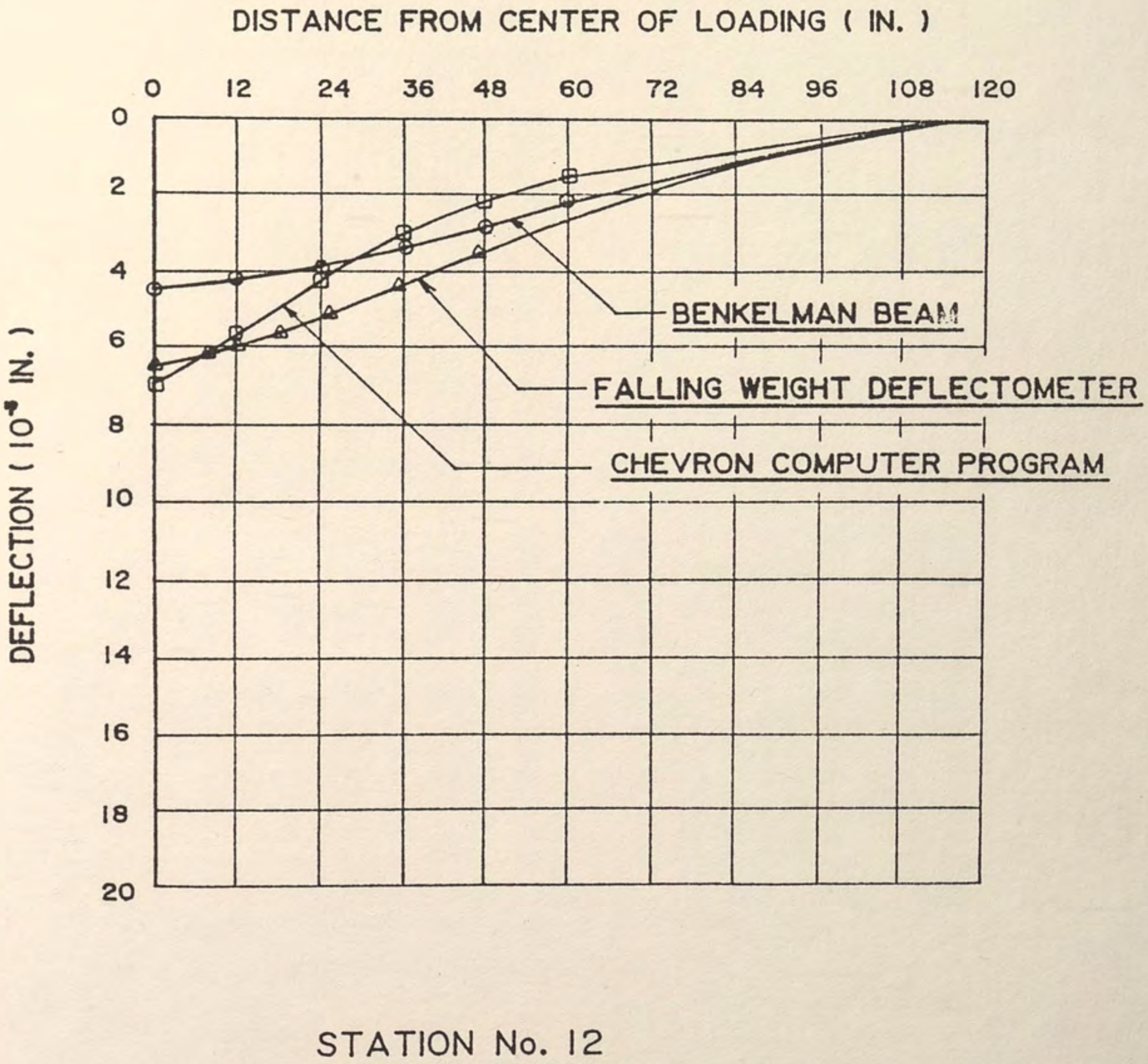

Figure 15. Deflection Basin from Station No. 12

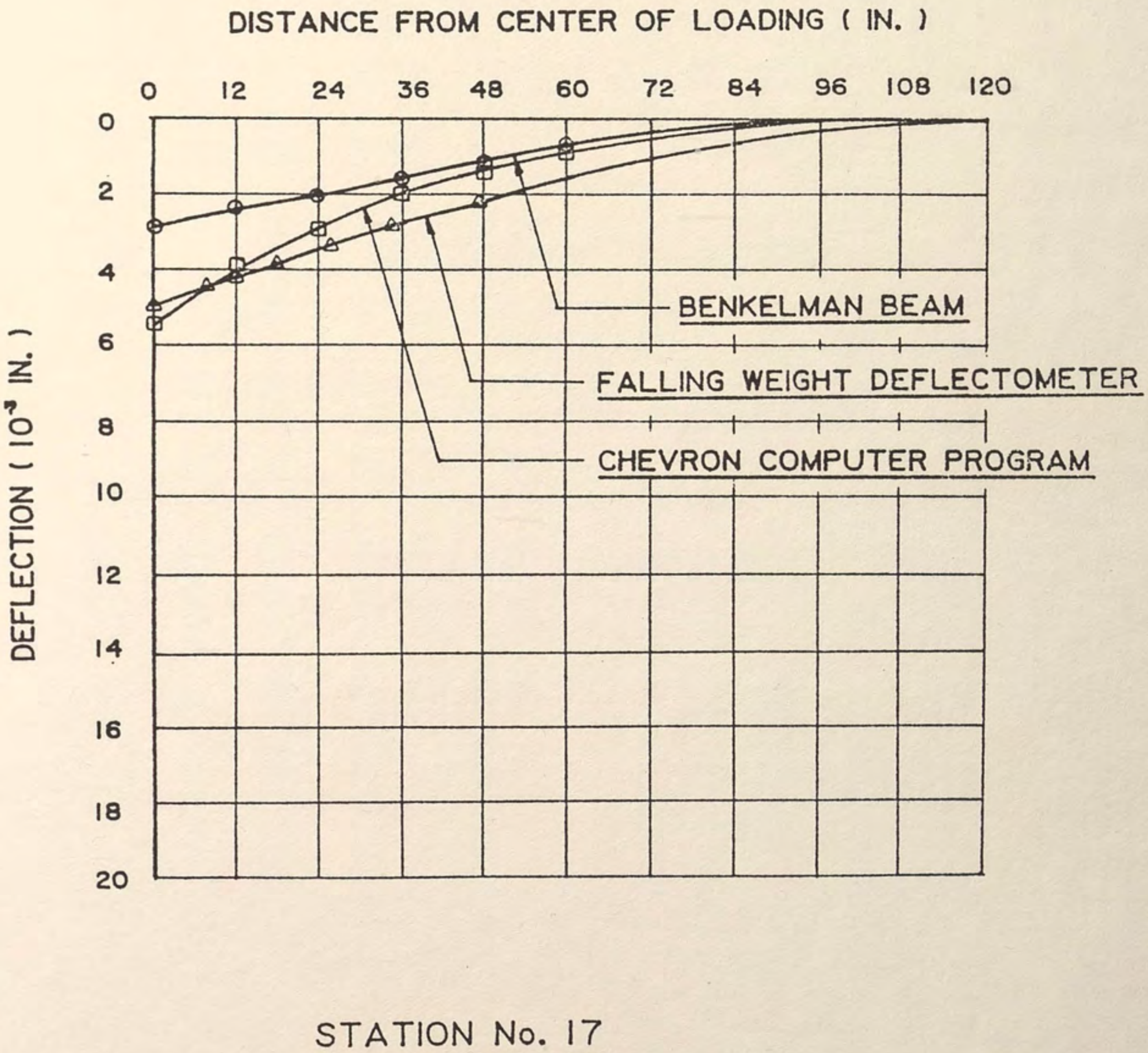

Figure 16. Deflection Basin from Station No. 17

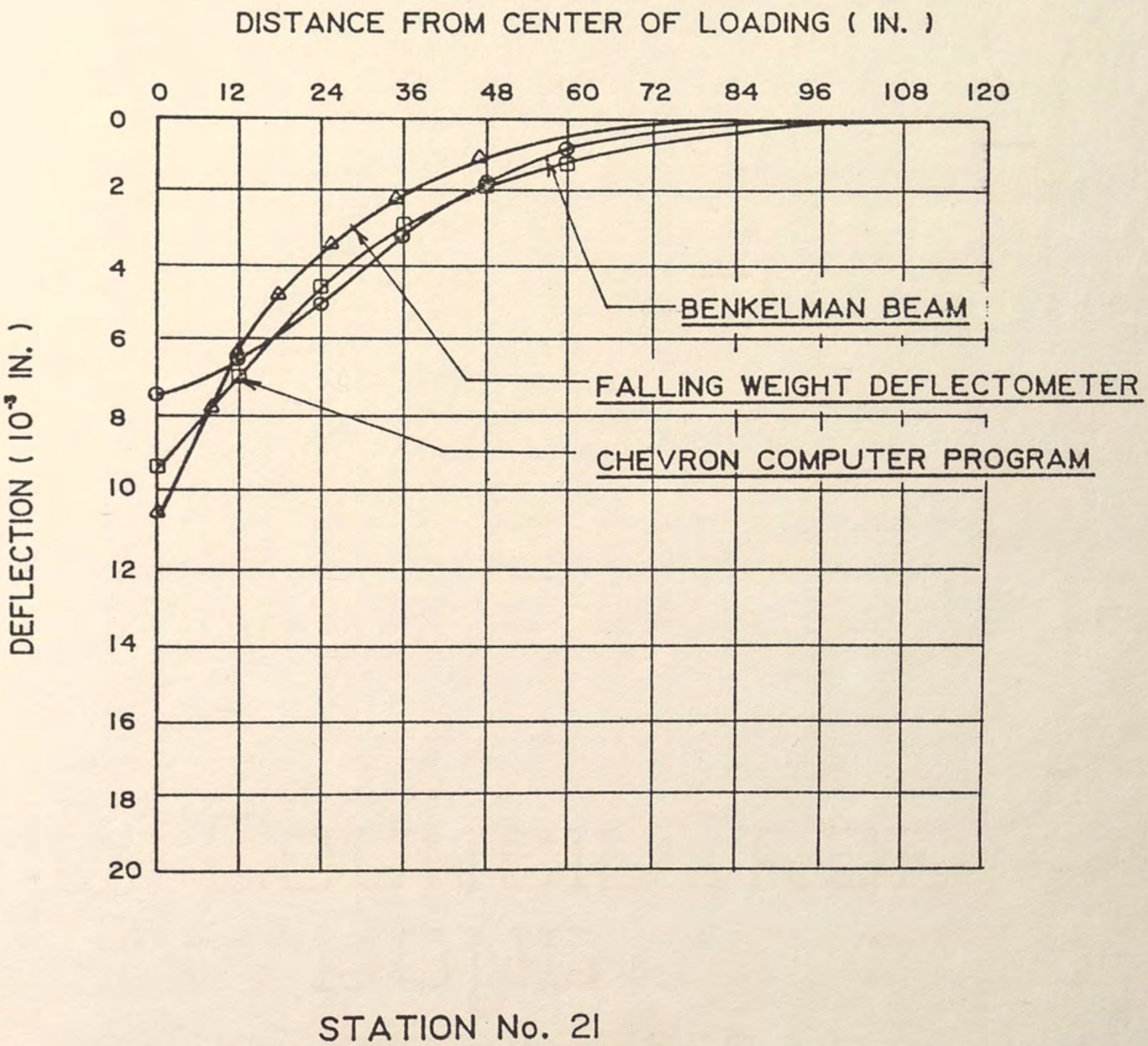

Figure 17. Deflection Basin from Station No. 21

Table 10. Spreadability in percent

Station No.	Benkelman Beam Equipment	Falling Weight Deflectometer	Chevron Computer Program
1	59.31	56.18	45.49
6	57.76	59.90	45.49
8	43.68	51.35	42.45
10	56.73	56.59	43.99
12	61.08	83.02	47.50
17	55.57	77.86	43.63
21	43.81	49.07	41.43

Typical Spreadability Calculations for Station No.1

Benkleman Beam :

$$\frac{10.43+9.64+8.53+7.11+5.06+2.53+0}{7\text{x}10.43} = 59.31\%$$

Falling Weight Deflectometer :

$$\frac{13.79+12.80+9.49+7.01+5.22+3.66+2.26}{7\text{x}13.79} = 56.18\%$$

Chevron Computer Program :

$$\frac{12.86+10.06+7.26+5.04+3.43+2.30+0}{7\text{x}12.86} = 45.49\%$$

Figure 18 (2) represents the fatigue criterion for the asphaltic concrete layer and figure 19 (2)represents the criterion for the subgrade. These figures are used to calculate the total allowable 18-kip repetitions for fatigue failure and subgrade rutting of the existing pavement. These figures were not developed for the existing pavement that was being studied. Table 11 shows the tensile strain at the bottom of the asphaltic concrete layer, vertical compressive strain at the top of subgrade and allowable 18-kip repetitions for each. Since the fatigue failure and subgrade rutting curves were not developed for the existing pavement, the allowable repetitions may not be a very accurate number. The values of tensile strain at the bottom of asphaltic concrete layer and vertical compressive strain at the top of subgrade were obtained from the output using Chevron computer program.

The traffic count data was provided by Transportation Consulting Group located at Winter Park, Florida. The data was collected on April 15, 1986 and the volumes were as follows :

Roadway	Daily Volumes
Construction Entrance - East of Technology Parkway	726
Discovery Drive - Norht of Research Parkway	2,960
Research Parkway - East of Alafaya Trail	6,542
East of Barnett Bank	4,423
Science Drive - West of Technology Parkway	815
Northrop Building Site - East Entrance	194
Northrop Building Site - West Entrance	176

Based on the above traffic study, the total number of vehicles that travelled daily on the Research Parkway would be approximately 4423 which were the number of vehicles counted to the east of Barnett bank. The breakdown of the traffic was not done by the Transportation Consulting Group. For the purpose of this research study it was estimated that 10% of the vehicles travelled were 18-kip vehicles for the first 24 months and 5% of the vehicles travelled were 18-kip vehicles for the next 28 months. Total number of 18-kip repetitions were obtained per table 12.

The remaining life of the existing pavement was calculated by Minor's law (6). The remaining life was calculated by the equation,

$$D_r = \frac{N_f - n_t}{N_f}$$

Table 7 shows the results of the remaining pavement life.

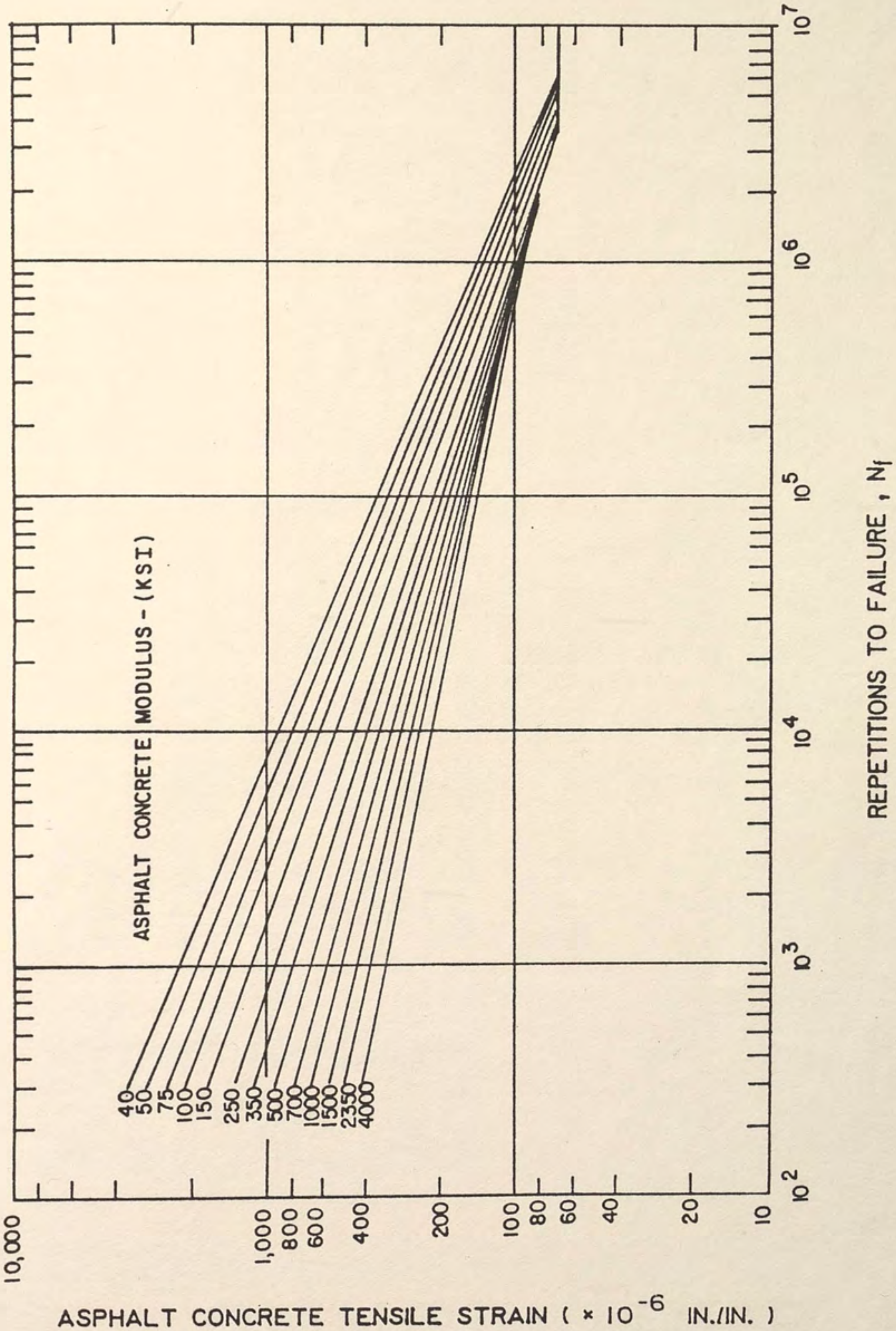

Figure 18. Fatigue Criterion for Asphaltic Concrete Layer

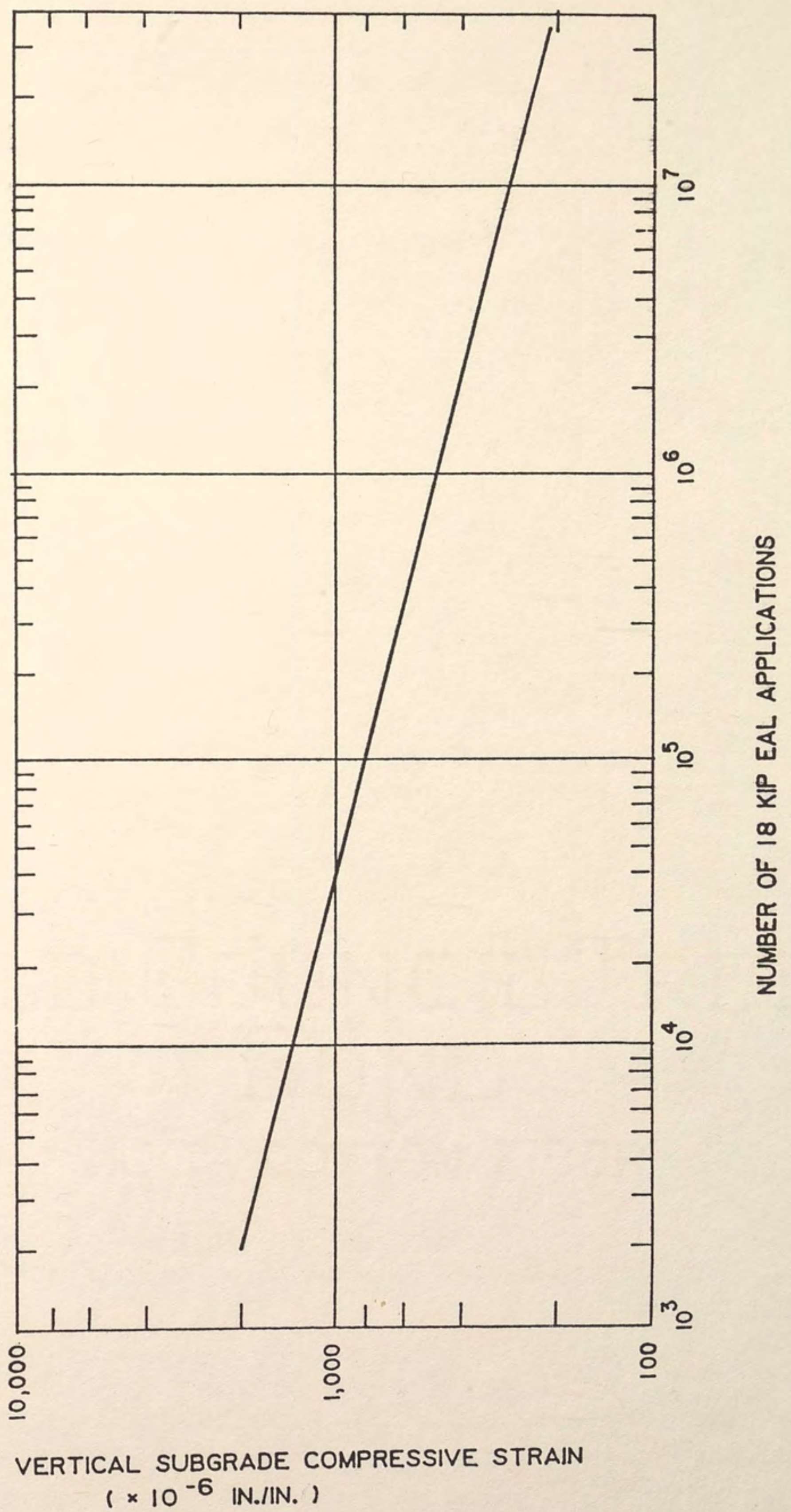

Figure 19. Fatigue Criterion for Subgrade

Table 11. Limiting Strains and Allowable 18-kip Axle Load Repetitions

Station No.	Tensile Strain at Bottom of Asphaltic Concrete Layer (in/in)	Vertical Compress. Strain at Top of Subgrade (in/in)	Allowable 18-kip Repetitions for Asph. Conc. Layer, N_f	Allowable 18-kip Repetitions for Subgrade N_f
1	-1.49×10^{-4}	5.92×10^{-5}	3.5×10^{5}	$>10^{7}$
6	-1.49×10^{-4}	5.92×10^{-5}	3.5×10^{5}	$>10^{7}$
8	-1.32×10^{-4}	5.60×10^{-5}	5.0×10^{5}	$>10^{7}$
10	-1.37×10^{-4}	6.60×10^{-5}	3.9×10^{5}	$>10^{7}$
12	-7.11×10^{-5}	4.82×10^{-5}	3.0×10^{6}	$>10^{7}$
17	-6.47×10^{-5}	3.96×10^{-5}	3.6×10^{6}	$>10^{7}$
21	-1.28×10^{-4}	5.10×10^{-5}	6.6×10^{5}	$>10^{7}$

Table 12. Daily 18-kip Repetitions

18-kip repetitions till data was collected

$$= 4423/\text{day} \times 0.1 \times 30 \text{ days} \times 24 \text{ months}$$
$$+ 4423/\text{day} \times 0.05 \times 30 \text{ days} \times 28 \text{ months}$$

$$= 504{,}222$$

$$= n_t$$

Table 13. Remaining Pavement Life

Station No.	n_t	$D_r = \frac{N_f - n_t}{N_f}$	Pavement Life, Yr.
1	504,222	N/A	Failed
6	504,222	N/A	Failed
8	504,222	N/A	Failed
10	504,222	N/A	Failed
12	504,222	83.19%	21.45
17	504,222	85.99%	26.60
21	504,222	23.60%	1.34

The reason for N/A is because the number of repetitions for failure are less than the number of 18-kip vehicles travelled during the period of time from the construction to the time the traffic count was made.

CHAPTER VI

SUMMARY & CONCLUSIONS

The results of this research report provided the following major conclusions.

1. The deflections profiles for Benkelman beam and falling weight deflectometer revealed similar results. This shows that these two methods match close to each other.
2. The deflection basins from repaired pavement show that deflection at center of wheel is much less for repaired pavement than the existing pavement. This was in agreement with the higher strength for repaired pavement.
3. The spreadability value for the bad pavement was much less than the spreadability value for the repaired pavement. This again was in agreement with higher strength for repaired pavement.
4. The allowable number of repetitions were lower based on tensile strain at the bottom of the asphaltic concrete layer at all sections. This suggests that the asphaltic concrete layer may be the primary reason for the early damage of the existing pavement.

The allowable number of repetitions for subgrade based on the vertical compressive strain at the top of the subgrade layer were higher. This indicates that the surface will not rut.

5. For stations no. 1, 6, 8, and 10 the allowable number of repetitions to failure were lower than the number of repetitions within past 52 months since the pavement is in use. This could be due to the fact that pavement asphaltic concrete layer had only 1.5 inches thickness. This thickness may not be sufficient to carry the loaded trucks that carried the heavy construction equipment. Also the high ground water table may deteriorate the pavement faster.

6. The analysis suggests that the asphaltic concrete layer may be predominant factor for the strength of pavement system. Reconstruction of new asphaltic concrete layer with proper D.O.T. construction procedure might correct the present problem.

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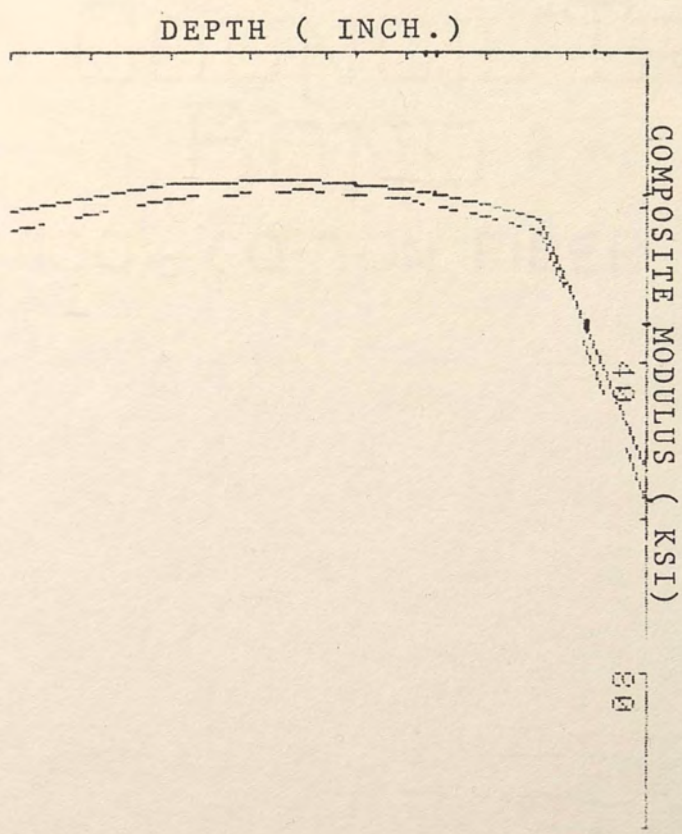
APPENDIX A

Falling Weight Deflectometer Computer Output

```
1610
File 8702    Rcd:28
8702     U.C.F. DEMO.
Stn:1           WhP:1        Tmp:81
\\:0 lbs   4878   5069   7262   8740
**:0 Df1   6.77   6.73  11.85  15.39
     Df2   6.38   6.30  11.10  14.29
     Df3   4.61   4.49   8.15  10.59
     Df4   3.39   3.46   6.02   7.83
     Df5   2.48   2.40   4.45   5.83
     Df6   1.73   1.73   3.07   4.09
     Df7   1.10   1.22   1.89   2.52
```



APPENDIX B

Typical Chevron Computer Program Output

LAYER	MODULUS	POISSONS RATIO	THICKNESS
1	300000.	.400	1.5 IN.
2	500000.	.200	8.0 IN.
3	15000.	.350	12.0 IN.
4	10000.	.350	SEMI-INFINITE

			S T R E S S E S				DISPLACEMENT		S T R A I N S	
R	Z	VERTICAL	TANGENTIAL	RADIAL	SHEAR	BULK	VERTICAL	RADIAL	TANGENTIAL	VERTICAL
.0	.0	-9.000E+01	-1.347E+02	-1.347E+02	.000E+00	-3.594E+02	1.484E-02	-1.494E-04	-1.494E-04	5.919E-05
				SLOW						
12.0	.0	-5.359E-01	-3.512E+01	-2.132E+01	1.583E-06	-5.697E+01	1.204E-02	-2.353E-05	-8.791E-05	7.346E-05
				SLOW						
24.0	.0	2.643E-02	-1.353E+01	-1.097E+00	1.339E-06	-1.460E+01	9.239E-03	1.435E-05	-4.367E-05	1.959E-05
				SLOW						
36.0	.0	2.419E-01	-5.408E+00	3.632E+00	1.323E-06	-1.534E+00	7.021E-03	1.900E-05	-2.319E-05	3.174E-06
				SLOW						
48.0	.0	-2.622E-01	-2.607E+00	3.511E+00	9.859E-07	6.420E-01	5.412E-03	1.553E-05	-1.302E-05	-2.080E-06
				SLOW						
60.0	.0	9.571E-02	-1.032E+00	3.098E+00	-2.372E-07	2.162E+00	4.278E-03	1.157E-05	-7.697E-06	-2.436E-06
				SLOW						
120.0	.0	-8.570E-02	-2.443E-01	3.989E-01	2.126E-08	6.893E-02	1.979E-03	1.770E-06	-1.232E-06	-4.918E-07
				SLOW						